CHAPTER 3

ENVIRONMENTAL CONSIDERATIONS FOR PRELIMINARY DESIGN

3-1. Introduction. Environmental factors should be considered from the outset of flood control channel project planning and design rather than as afterthoughts. Channel projects frequently offer unique opportunities for incorporation of environmental features. Integrating hydrologic, hydraulic, ecologic, aesthetic, and cultural considerations in the design process is necessary because natural streams are systems composed of interrelated physical, chemical, and biological subsystems that are uniquely characteristic to each project.

a. Subsystem Linkage. Stream systems are complex and often differ from one another with respect to physical and chemical characteristics and biological community structure. Chemical and biological subsystems depend to a large extent on watershed characteristics, stream hydrology, and climatic conditions. Relationships between watershed conditions and stream characteristics are discussed in paragraph 3-3.

(1) Chemical subsystem. Stream water chemistry reflects the geology and local climate in the drainage basin and any point or nonpoint source pollution. Water temperature, which controls the solubility of both gases and solids and the rates of chemical reactions, is controlled by climate, water source, water use, flow depth, and, for narrow streams, shade.

(2) Biological subsystem. The plant and animal communities of a given stream are governed both by water quality and the physical characteristics of the stream. Winger (1981) presents a thorough literature review of stream characteristics and a general classification of small streams as warmwater or coldwater; each type has a characteristic morphology, chemical regime, and biological assemblage (Table 3-1).

b. Human Use. Human use of a given stream for recreation or water supply is also governed by the constraints imposed by the physical, chemical, and biological subsystems. For a given level of demand, recreational use depends on width, depth, velocity, accessibility, and water quality. Water clarity and bacterial quality are most often used in stream recreation criteria. Fishery and wildlife resources are controlled by the biological subsystem and are subject to all the influences it experiences. The aesthetic value of a stream is a function of the diversity and composition of the water resource itself, riparian vegetation, surrounding landforms, and adjacent land uses.

c. Systems and Design. The net environmental effect of stream channel modification can be improved by studying the effects on the chemical and biological subsystems from alteration of the physical subsystem. In particular, the designer should strive to maintain the existing width, depth, velocity, and bed material size. Actions that reduce shade (from riparian trees and shrubs) are particularly undesirable for small, low-order streams because cover is an important habitat feature. An integrated approach to planning and design that considers effects on chemical and biological subsystems and

Table 3-1. General Characteristics of Warmwater and Coldwater Streams

Characteristic	Coldwater	Warmwater
Geology	Youthful	More mature
Valley shape	V	U
Temperature	Cold (<20° C)	Cool-warm (>20° C)
Discharge	Low	Medium-high
Velocity	Moderate (high turbulence)	Moderate to high (low turbulence)
Depth	Shallow	Medium to moderate
Width	3 to 20 feet	>10 feet
Bed material	Rubble-gravel	Rubble-sand-mud
Gradient	High	Low
Elevation	High	Low
Turbidity	Clear	Clear-turbid
Pools (riffles)	Short (many riffles)	Long (few riffles)
Temporal variability	High	Low
Aquatic flora	Periphyton	Macrophytes
Shade and cover	Extensive	Sparse
Organic material	Coarse particulate organic matter	Fine particulate organic matter
Distance from source	<5 miles	>10 miles
Stream order	Low (<3)	High (>3)
Competition	Intraspecific	Interspecific
Predatory fish	Few	Many
Fish community	Trout	Bream, bass, sunfishes, catfish, suckers
Fish diversity	Low	High

Source: Winger (1981).

potential human uses can result in a project that is superior in many respects even to preproject conditions.

3-2. Water Quality.

a. General. Water quality in streams depends on chemical and physical properties as reflected by such conditions as nutrient enrichment, turbidity, temperature, dissolved oxygen concentration, atypical concentrations of biodegradable organic materials, and the presence of toxins and other harmful chemicals. Deteriorated water quality not only affects aquatic ecosystems but is often associated with degraded appearance and unpleasant odors and can influence the use and management of water resources.

b. Controls on Stream Water Quality.

(1) Watershed conditions. Water quality in streams is largely a function of watershed and stream characteristics. Streams draining undisturbed watersheds contain suspended and dissolved substances provided by natural weathering of rocks and minerals. Concentrations beyond these natural background levels reflect temporary natural disturbances, such as volcanic eruptions, forest fires, and landslides, or human activities such as agriculture, irrigation, mining, logging, construction, and waste disposal. Human land-disturbing activities and some types of natural catastrophes alter rainfall-runoff relationships and supply large quantities of sediment and nutrients that increase stream turbidity levels, especially during high-discharge events. Erosion of streambeds and banks caused by increased runoff rates and frequencies also contributes to increased turbidities.

(2) Hydrology. Drainage basin hydrology greatly influences water quality. Streams draining areas with low precipitation and sparse vegetation have higher sediment concentrations than streams in more humid regions. During low-discharge periods, streams may have higher water temperatures, lower oxygen concentrations, nutrient enrichment, higher pollutant concentrations, and lower sediment concentrations than during high-flow periods. High discharges, on the other hand, typically have increased sediment concentrations, and stormflows may contain increased pollutant loads, especially in large urban and agricultural areas.

(3) Turbulence. Several aspects of stream water quality are related to turbulent flow. The amount of surface reaeration depends on turbulence, which is largely dependent upon stream gradient, roughness elements, and flow depth. Steep, shallow, high-velocity streams are well oxygenated and well mixed and are more capable of oxidizing organic materials than deep, low-gradient streams with similar temperature regimes. Suspended sediment concentrations, and thus turbidities, are directly related to turbulence.

(4) Organic and chemical pollutants. Stream pollution is typically categorized as originating from either point sources or nonpoint sources. Sewage treatment plants, industrial operations, accidental spills, and other point sources release a variety of substances into streams, some of which are highly toxic. Urban and agricultural runoff are the most common nonpoint sources and supply large quantities of organics, nutrients, and chemical residues from pesticides and herbicides.

c. Cause-Effect Relationships. Although it is clear that water quality is the product of watershed conditions, human activities, and stream characteristics, the effects are often additive in nature. Thus, except for pollutants that may be traced to single sources due to their geographic location or temporal occurrence, or those pollutants that are uniquely associated with specific sources for functional reasons (such as dye used in only one type of manufacturing operation), it may be difficult to isolate individual cause-effect relationships that determine water quality.

d. Data Sources.

(1) Published data. Published water quality data are available from several sources, some of which are listed in Appendix B. Caution should be exercised in extracting data from the public data sources to ensure that meaningful and high-quality data are used.

(2) Data collection. Refer to Chapter 6 for general guidance on data collection.

e. Effects of Flood Control Channel Projects on Water Quality. Water quality parameters that may be affected directly by channel modifications for flood control are turbidity, temperature, dissolved oxygen, and organic constituents. Dredging, excavation, and disposal may release various chemicals through resuspension and leaching. Nutrient levels, chemical pollutants, and turbidity may be increased indirectly as a result of induced land use changes. Studies of the effects of channel projects on water quality are presented in Kuenzler et al. (1977), Simmons and Watkins (1982)., and Shields and Sanders (1986).

(1) Turbidity and suspended sediment. Without preventive measures during construction, turbidity and suspended sediment levels may increase as much as an order of magnitude. Pronounced increases tend to be short term, but postconstruction levels sometimes continue above preconstruction levels due to higher flow velocities, channel erosion, and sediment derived from induced land use changes such as agricultural land conversion. Erosion and sedimentation associated with high sediment concentrations can destroy spawning habitat for fish and benthic substrates critical to macroinvertebrates.

(2) Water temperature. Temperature is an important water quality parameter because it influences chemical and biological stream processes. Aquatic organisms are extremely sensitive to increases in temperature above ambient conditions, and temperature increases may induce early spawning of many organisms. Removal of shade has been observed to result in higher temperatures (1° to 10° C) in and below modified reaches. Channel linings such as concrete further aggravate this condition. Temperature effects of channel modifications may decline through time if shade-producing vegetation is allowed to become reestablished along streams.

(3) Dissolved oxygen. Studies of the effects of channel modifications on dissolved oxygen concentrations have found no effects in some cases and beneficial effects in others. Modifications that increase flow velocities or that convert intermittent streams into permanently flowing streams often produce increases in dissolved oxygen concentrations.

(4) Chemical constituents. Where reduced threat of flooding has encouraged urban development or widespread clearing of land and expansion of agriculture, nutrient levels are often higher in modified than in unmodified channels. Modern agriculture relies heavily on fertilizers, pesticides, and herbicides. Livestock operations generate large volumes of animal wastes that are difficult to dispose. As a consequence, any expansion or intensification of farming operations is likely to result in increased amounts of nutrients, sediments, and bacteria in streams. Induced effects of channel modifications such as these tend to be long term and are likely to intensify through time. A variety of other chemical concentrations may be affected by channel modifications, especially if the channel is excavated or dredged. Soils or sediments exposed by excavation or material disposal may be leached of heavy metals or other substances, some of which may be hazardous or toxic.

f. Water Quality and Project Design. Water quality can influence and be influenced by project design. Many features designed to improve environmental benefits of flood channel projects will not work or will produce few benefits if placed in channels with poor water quality. Conversely, channels can be designed so that water quality is enhanced rather than degraded. Information concerning water quality impacts on flood channel design and environmental features to improve water quality can be found in WES TRs E-82-7 and E-85-3. Sources of water quality data are discussed in Appendix B.

(1) Prediction of effects. In many cases it is possible to predict the type and relative magnitude of changes in water quality of flood control channels with water quality models. These models must include the appropriate mechanisms for simulating transport processes and various physical, chemical, and biological characteristics. Numerical and physical models have been used to estimate erosion and sedimentation in flood control channels. The accuracy and usefulness of water quality/sediment transport models are very dependent upon the skill of the modeler and the quality of the data. The proper application of many models requires training and experience. Although the capabilities for modeling water quality and sediment transport have advanced substantially, it is still difficult to assess the impact of water quality changes on biological resources. Even when sufficient data are unavailable to permit the use of empirical formulas or models, some notion of expected water quality effects can be gained by investigating similar project designs nearby or those located in similar environments elsewhere.

(2) Water quality and environmental features. Biological productivity and aesthetic and recreational benefits of flood control channels are strongly influenced by water quality. Aquatic productivity is influenced by a variety of physical and chemical water quality parameters, including dissolved oxygen, suspended sediment, temperature, nutrients, and presence of hazardous or toxic substances. Water quality parameters that influence appearance and odor have the greatest effect on aesthetics. Recreational benefits are also influenced by odor and appearance, but the presence of biological or chemical contaminants may be the overriding concern for boating and swimming. (Refer to US Environmental Protection Agency, EPA 400/5-86-0001, Quality Criteria for Water 1986, for the water quality criteria for aesthetics, recreation, and aquatic life.)

(3) Preventive measures. Opportunities exist during the planning, design, construction, and maintenance of flood channels to improve water quality or prevent deterioration. WES TR E-85-3 presents information and procedures for selecting and designing features that improve water quality conditions in flood channels.

(a) Short-term water quality impacts associated with construction can be reduced by employing dry construction techniques; using erosion and sediment control devices such as sediment basins; scheduling construction in stages or steps; minimizing areas disturbed and exposure time; protecting disturbed soils with mulches, covers, and chemicals; and using flocculants to induce sedimentation. Techniques for reducing erosion and sedimentation from construction sites can be found in WES Instruction Report (IR) EL-83-l and in manuals, including those by the Soil Conservation Service, US Department of Agriculture (1973), Hittman Associates (1976), and Amimoto (1978).

(b) Existing streamside vegetation can be preserved and new plantings can be designed to provide shade, organic matter, and wildlife and fisheries habitat. Selective clearing and snagging, single-bank construction, and other techniques to preserve vegetation are discussed in WES TR E-85-3.

(c) Instream structures such as fish habitat devices, weirs, and drop structures can be used to add turbulence and to maintain flow through cutoff bendways. In some instances it may be beneficial to supplement inflows to cutoff bendways by pumping. Water quality on completed projects can be improved by coordinating with State and local governments to control pollution through zoning, enforcement of water quality legislation, and employment of best management practices to control runoff and erosion in agricultural areas.

3-3. Fluvial Geomorphology.

a. General. Streams are complex systems composed of hydraulic, geomorphic, biologic, and physical-chemical components. The stream system, in turn, is one part of the overall fluvial system that includes the watershed (Table 3-2). Streams that drain unaltered or undisturbed watersheds tend to be morphologically stable, transporting the water and sediment loads imposed from the watershed without enlarging or aggrading. Human activities or changes in natural conditions in a watershed affect the discharge of water and sediment and can trigger changes in stream systems. In a similar fashion, changes in one parameter of the stream system--water and sediment discharge, slope, channel roughness, width, depth, or channel pattern--may induce changes in one or more of the others. It is therefore essential that those involved in the planning, design, construction, and maintenance of flood control channel projects understand the necessity of treating the stream, its watershed, and associated resources as a unified system. The stability of this system may be studied through geomorphic and sedimentation analyses. These analyses are valuable tools for estimating stream response to channel modifications and the effect of ecological resources. They consist of assessing the stability of the existing system and the system’s potential response to project modifications.

b. Ecological Implications of Geomorphic Change. Watershed changes, channel modifications, and resulting geomorphic changes affect aquatic habitat

Table 3-2. The Watershed Subsystem

Watershed Characteristic	Process	Response
Precipitation	Interception	Soil moisture
Solar radiation	Evapotranspiration	Ground water
Temperature	Infiltration	Water discharge
Vegetation and land use	Throughflow	Sediment discharge
Soils	Overland flow	
Geology	Soil erosion	
Topography		

and ecological resources. Erosion in degrading channels produces unstable substrate and may undermine habitat structures and water control structures. Sediment from disturbed watersheds or eroding channels produces sandy, shifting substrate with little habitat value, fills pools and low-flow channels, and covers structures that provide fish habitat. At low flows, large flood control channels typically have shallow depths and uniform flow velocities, whereas at flood discharges they have uniformly high velocities with little cover to provide protection for fish. Geomorphic and sediment analyses can be valuable tools for estimating stream response to channel modifications and the effect on ecological resources.

3-4. Ecological Resources.

a. General. It is a national policy that fish and wildlife resources conservation be given equal consideration with other study purposes in the formulation and evaluation of alternative plans. Fish and wildlife resources include vertebrate and invertebrate animals and their habitat. Streams and adjacent riparian areas are often important and highly valued ecosystems.

b. Effects on Fish and Wildlife. The potential effects of an action (such as lining a stream) on fish and wildlife resources must be described and analyzed before the action is taken. Guidance on this is provided in ER1105-2-100 and its references. There is an assumed positive relationship between habitat quality and fish and wildlife populations, and ER 1105-2-100 requires use of habitat-based methods, supplemented with user-day, population census, or other quantified information, for fish and wildlife impact analysis.

(1) Habitat-based evaluation methods use species, groups of species, or entire animal communities as evaluation elements. The quantity of available habitat is determined from maps and photographs. Habitat quality is derived from a model that relates features of the environment to habitat requirements of the selected species or other evaluation element. The model may be mathematical or descriptive. The more objective and documented the approach, the more repeatable the process. The habitat evaluation method to be applied

should be compatible with project needs in purpose and level of detail. Examples of the various habitat evaluation methods are provided in WES Miscellaneous Paper EL-85-8 (Roberts and O'Neil 1985), and assistance in applying these methods is provided in WES IR EL-85-3 (O'Neil 1985).

(2) A direct evaluation of a species, not just its habitat, may be warranted for species protected by law or those of special significance in the project area. Examples include endangered or threatened species and major sport or commercial fisheries such as salmon. Other fish and wildlife considerations are addressed in ER 1105-22-100.

3-5. Cultural Resources.

a. General. Cultural resources are the physical evidence of past and present habitation that can be used to reconstruct or preserve the story of human presence in an area. This evidence consists of structures, sites, artifacts, and other relevant information about an area. Corps projects must comply with the National Historic Preservation Act (NHPA) and the Archeological and Historic Preservation Act. These Acts require that the impact on significant historic sites or resources be considered and that adverse impacts be minimized through development of management plans for protection of historic and cultural resources affected by a project. Up to 1 percent of the total Federal authorized costs, after the feasibility stage, may be spent for identification, recovery, and preservation of historic properties at authorized Civil Works projects. Compliance with these requirements is accomplished through coordination with the State Historic Preservation Officer (SHPO) and the Advisory Council on Historic Preservation (ACHP). Guidance on consideration of cultural resources is provided in ER 1105-2-100, chapter 7.

b. Cultural Resource Inventory and Impact Assessment. The identification of cultural resources in the study area is accomplished through review of the National Register of Historic Places, the archives and other files of the SHPO, other public records, and prior historic resource investigations. Historic and cultural resources are identified for possible eligibility for National Register listing. An assessment is made of the predicted impact to the identified cultural resources. If properties listed or eligible for listing in the National Register will be affected, review and comments by the SHPO and and ACHP must be obtained pursuant to Section 106 of the NHPA and 36 CFR 800.

c. Mitigation of Adverse Impacts. Prior to construction, plans are developed for mitigation of adverse impacts to properties listed or eligible for listing in the National Register of Historic Places. After the impact assessment described in the preceding paragraph, more extensive surveys, testing, and determination of eligibility for National Register listing may be required. Based on any additional documentation, plans are developed for mitigation of adverse impacts. A Memorandum of Agreement (MOA) is negotiated between the Corps of Engineers and the ACHP and SHPO. The MOA specifies the actions that will be taken by the Corps during project construction to mitigate adverse effects on National Register and eligible properties.

3-6. Aesthetic Resources.

a. General. Streams and adjacent riparian areas are often highly valued as aesthetic resources. An assessment of existing visual quality and evaluation of visual impacts should be a part of planning and design. Procedures for evaluating visual quality and impacts have been developed by the WES (see WES IR EL-88-1).

b. Visual Impact Assessment.

(1) The visual impacts resulting from a flood control channel should be assessed early enough in planning and design so that measures can be taken to minimize adverse impacts, protect existing visual quality, or improve degraded visual quality considerations. The evaluation of the extent and beneficial or adverse nature of visual impacts is dependent in part on the existing visual quality. The acceptability and compatibility of flood control design is affected by the project setting and the expectations of users, e.g., recreationists, residents, or workers in an industrial area. The visual quality of a project area may be improved by a channel project when, for instance, denuded, eroding banks are replaced by a stable bank line and grassed banks.

(2) Visual impact assessment is accomplished by comparing with- and without-project conditions. If resources are not available for preparation of visual simulations, visual impact assessment is limited to determining the changes in vegetation, landform, and other visual resources. Visual simulations of alternative designs can be developed through sketches, rendering (painting the design on a photograph), and a number of computer-assisted methods. After the visual effects have been assessed, adverse visual impacts are identified. These adverse visual impacts provide the basis for reformulation of the project or for implementation of design and construction measures to minimize adverse impacts.

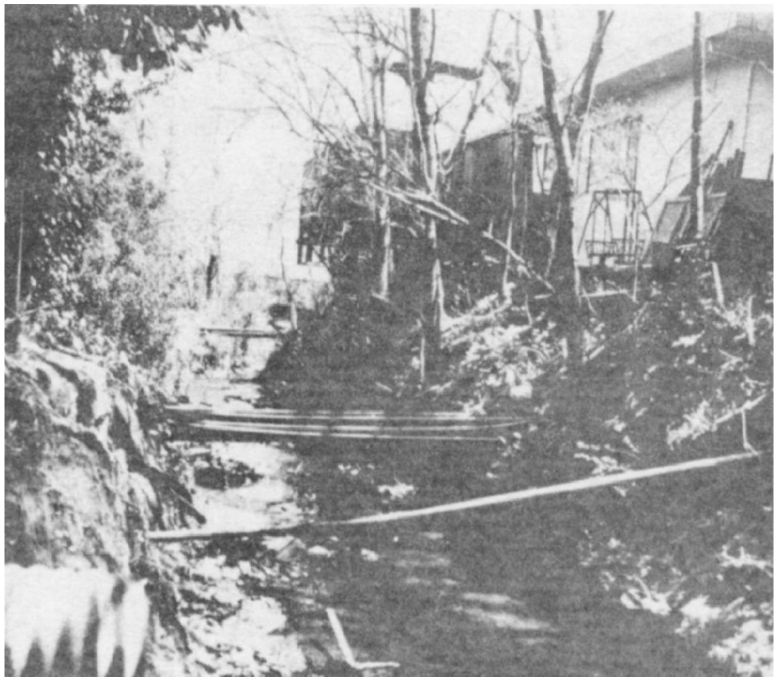
c. Measures to Protect and Maintain Visual Quality. Design, construction, and operation measures can be used to protect and maintain the visual quality of flood control projects. These measures include the following:

(1) Use of vegetation and natural materials can reduce the visual contrast of a flood control structure with the project setting. Vegetation and natural riverine substances, e.g., gravel and rock, can be used alone or in combination with structures to provide a more natural appearance. Minimizing the extent of bank and streamside clearing and using vegetation in the design preserve the natural appearance of the project setting. Restoration of excavated, eroded, and cleared areas can be performed as part of construction activities.

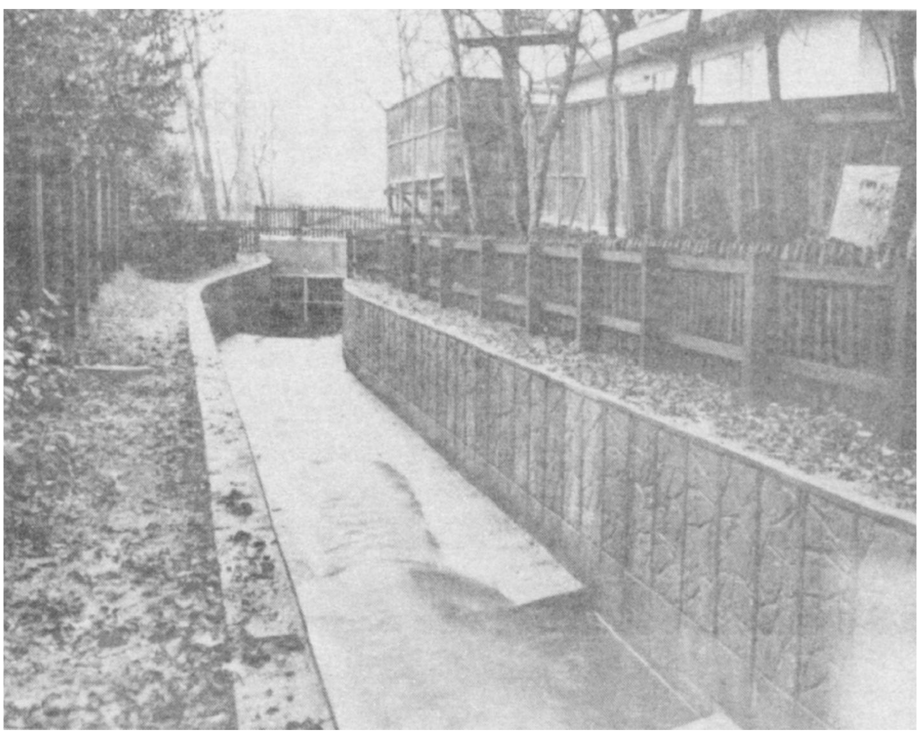
(2) Changes in design elements can improve the visual compatibility of a channel design within a project setting. The design elements of concern are form, line, color, texture, and scale. Depending upon the limits of performance and costs, the various design elements can be changed to improve the visual aspects of the project. For example, concrete can be textured to pick up the texture patterns of the bank line setting. Excavation and disposal areas can be contoured to reproduce the form and scale of the existing landscape. Color can he manipulated in concrete admixtures, staining of grout.

and use of vegetation. Subject to other project design and maintenance constraints, vegetation can be used to modify or screen structural forms and lines. Figure 3-1 depicts a flood control project on Tamalpais Creek. California, that was constructed by the US Army Engineer District, San Francisco. and incorporates several aesthetic measures.

(3) Construction and maintenance procedures can be modified or to minimize destruction of vegetation. Water-based construction minimizes the need for haul roads and clearing for access. Similarly, construction single side of the stream limits the amount of required clearing.



a. View before project



b. View after project. The curving alignment, redwood fence, and special concrete finish contribute to visual effect

Figure 3-1. Enhancement of flood channel aesthetics, Tamalpais Creek, Calif.